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PROBLEMS OF MARINE ECOLOGY[1]

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Even if one should have the daring to suggest that conditions of life in the sea are any less complex than those upon land, he must admit that the greater difficulty in gathering adequate data (except for certain aspects of various littoral problems) concerning even the simplest phases of oceanic relationships, organic or inorganic, renders any extensive investigation of ocean life much more formidable than any similar investigation on land. For this condition there are valuable compensations in the greater general stability of certain fundamental factors of ocean life such as temperature, water, minerals, gases and pressure which open the way for illuminating comparisons and for segregation of influences not readily found under natural conditions on land. Indeed it is not too much to say that a careful study of marine ecology will do much to aid in forwarding an understanding of life and the conditions of life on the land.

In the hope of encouraging more extensive study in the field of marine ecology, the following tentative outline is suggested. The complexity of the subject and the vastness of the field make such an outline seem inadequate and the writers' great hope has been that it may serve as a concrete basis for the development of a practicable plan of research upon these problems in the future.

I. Factors influencing the distribution of pelagic organisms.
  A. Geographic position.
    1. Latitude.
    2. Longitude.
    3. Depth.
      (*a*) Below surface.
      (*b*) Distance above bottom.

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[1] In the statement of ecological problems prepared by the Committee on Cooperation of the Ecological Society and published in Science, N. S., Vol. 51, No. 1307, pages 66–88, January 16, 1920, under the title "The Ecological Society and Its Opportunity," the problems of marine ecology were not adequately considered. Dr. Michael was asked to prepare the accompanying outline in order to correct the misapprehension which the above mentioned outline had caused among marine biologists. Dr. Michael died on August 30, 1920, before this outline was quite finished, and it has been completed and revised by Dr. Allen with the assistance of Dr. Ritter.—Barrington Moore, *Chairman Committee on Cooperation.*

  4. Distance from mainland.
  5. Proximity to islands, banks, reefs, shoals, etc.

B. Time.
  1. Date.
  2. Hour.
  3. Cycles, single and combined.

C. Physiographic factors.
  1. Major ocean currents (Constant, *e.g.*, Gulf Stream, Japan Current).
  2. Contour of sea floor.
  3. Accumulation and distribution of sediment from land drainage.
  4. Character of drainage materials.

D. Hydrographic factors.
  1. Minor currents (variable).
    (*a*) Direction and velocity at observation.
    (*b*) Source and general course.
    (*c*) Eddies and whirlpools.
    (*d*) Streaks (junction of two or more currents).
    (*e*) Tides.
  2. Other water movements.
    (*a*) Waves, ripples, breakers, etc.
    (*b*) Storm movements.

E. Meteorologic factrs.
  1. Light (direct, diffuse, oblique).
  2. Solar radiation or insolation.
  3. Precipitation (rain, sleet, snow, etc.).
  4. Direction and velocity of wind (important in aerating water, generating currents and direct transport of certain organisms).
  5. Barometric pressure.

F. Properties of water.
  1. Physical.
    (*a*) Temperature.
    (*b*) Density.
    (*c*) Viscosity.
    (*d*) Color and turbidity.
    (*e*) State (ice, icebergs, etc.).
  2. Chemical.
    (*a*) Salinity and mineral content.
    (*b*) Acidity or alkalinity.
    (*c*) Organic content.
    (*d*) Gaseous content.

G. Biotic factors.
  1. Organisms of primary investigation.
    (*a*) General morpho-physiological facts and principles.
    (*b*) Stages in life history or histories.
    (*c*) Reproductive phenomena, including breeding habits.
    (*d*) Rhythmic and periodic activities.
    (*e*) Foods and feeding habits.
    (*f*) Influence upon their environment.
    (*g*) Nature and manner of response to stimuli.
  2. Other organisms requiring attention.
    (*a*) Abundance.
    (*b*) Types and characteristics.
    (*c*) General relationships to central problem.
    (*d*) Beneficial relationships to primary organism.
      1. Food.
      2. Protection { Direct.
        Indirect. (Remove competitors, enemies, etc.)
      3. Symbiosis.
    (*e*) Harmful relationships to primary organisms.
      1. Predatory activities.
        Destruction.
      2. Parasitism.
      3. Competition.

II. Factors influencing the distribution of benthic organisms.
  Class 1. Littoral forms.
    A. Geographic position.
      1. Latitude.
      2. Longitude.
      3. Proximity to rivers and streams.
      4. Proximity to active volcanoes.
      5. Shelter from open sea.
    B. Time (same as under I, *B*, above).
    C. Physiographic factors.
      1. Depth of water.
      (*a*) At tidal limits.
        (*b*) Alteration of depth by shifting bars, etc.
      2. Sea floor.
        (*a*) Slope and contour.
        (*b*) Structural character (rock, sand, clay, etc.).
        (*c*) Recent deposits (kind, depth, permanency).
      3. Adjacent land.
        (*a*) Shape and trend of coast line.

      - (*b*) Drainage area (extent, character).
      - (*c*) Drainage material (amounts of materials, character of materials).
      - (*d*) Influence of fresh water.
  - *D*. Hydrographic factors.
    - 1. Minor currents (variable).
      - (*a*) Direction and velocity at observation.
      - (*b*) Source and general course.
      - (*c*) Tides (velocity and extent of ebb and flow, etc.).
    - 2. Other water movements.
      - (*a*) Waves, ripples, breakers, etc.
      - (*b*) Storm movements.
  - *E*. Meteorological factors (same as under I, *E,* above).
  - *F*. Properties of water (same as under I, *F,* above).
  - *G*. Biotic factors (same as under I, *G,* above).
- Class 2. Abyssal forms.
  - *A*. Geographic position.
    - 1. Latitude.
    - 2. Longitude.
    - 3. Proximity to rivers and streams (influence on pelagic organisms whose bodies sink).
    - 4. Proximity to active volcanoes.
    - 5. Distance from dry land.
  - *B*. Time (same as under I, *B,* above).
  - *C*. Physiographic factors.
    - 1. Depth of water.
    - 2. Sea floor.
      - (*a*) Slope and contour.
      - (*b*) Structural character (rock, clay, etc.).
      - (*c*) Recent deposits.
        - 1. Organic
          - Kind.
          - Amount.
          - Composition.
        - 2. Inorganic
          - Kind—volcanic ash, etc.
          - Amount.
          - Composition.
  - *D*. Hydrographic factors (same as II, *D,* above, with omission of Tides).
  - *E*. Properties of abyssal water.
    - 1. Physical.
      - (*a*) Temperature.
      - (*b*) Density.
    - 2. Chemical (same as under I, *F,* 2, above).
      - *G,* 1, above, with addition of Phosphorescence).

- *F*. Biotic factors.
  - 1. Organisms of primary investigation. (Same as under I, *G*, 1, above, with addition of Phosphorescence).
  - 2. Other organisms requiring attention.
    - (*a*) Fauna and flora of higher strata.
      - 1. Abundance.
      - 2. Composition.
    - (*b*) Rate of descent of organisms of higher strata.
    - (*c*) Influence of organisms at intermediate depths.
    - (*d*) Phosphorescence.

III. Some of the major problems of marine ecology.

- *A*. Plankton problems.
  - 1. Seasonal variation in plankton production: its causes and effects.
  - 2. Relation of plankton production to depth of water and proximity to land: and the extent to which the metabolic cycle in the sea is a closed one.
  - 3. Relation of plankton production and distribution to the system of oceanic circulation.
  - 4. Relation of plankton production to bacterial action, and to the chemical constituents of the water, both organic and inorganic.
  - 5. The problem of the vertical distribution of plankton, and the significance of, and reasons for, variations in this distribution from time to time and place to place.
  - 6. Relative fertility of hydrographically diverse oceanic areas, and its relation to bottom deposits, especially in regions remote from land.
  - 7. Nature and magnitude of the effect of variations in plankton production and distribution upon the fisheries.
- *B*. Field survey of problem.
  - 1. Definition of physical, chemical and biotic characteristics of region with a view toward location of collecting stations.
  - 2. Quantitative collection of organisms under investigation, and simultaneous measurement of relevant environmental conditions.
  - 3. Discovery of correlations between variations in number of organisms collected and fluctuations in relevant environmental conditions.
  - 4. Testing the significance of correlations by statistical methods.
- *C*. Laboratory studies.
  - 1. Behavior under controlled conditions with a view toward explaining correlations revealed by field records.
  - 2. Similar studies with a view toward suggesting more critical field investigations.
- *D*. Field interpretations of laboratory results.